2nd INTERNATIONAL SEMINAR ON APTERYGOTA
R. Dallai editor

INFLUENCE OF THE CYCLOMORPHOSIS ON THE WINTER BEHAVIOUR OF *ISOTOMA HIEMALIS* (COLLEMBOLA)*

J. ZETTEL AND U. ZETTEL

Zoologisches Institut der Universität Bern
Baltzerstrasse 3, CH-3012 Bern, Switzerland

Introduction

Activity on the snow surface is known from a number of Collembola of the families Isotomidae and Poduridae. In some of them, this behaviour is connected with a cyclomorphosis: in *Isotoma hiemalis* (Fjellberg 1976), *Hypogastrura socialis* (Leinaas 1981a) and *Hypogastrura lapponica* (Leinaas 1981b). Since 1978 we are investigating the cyclomorphosis of *I.hiemalis* and its biological consequences in a subalpine spruce forest in the Swiss Prealps at 1580 m a.s.l.. The winter morph (*I.h.hiemalis*) appears from the end of October onwards and differs from the summer morph (*I.h.mucronata*) in the shape of the mucro (Fjellberg 1976, Zettel 1985) as well as in behaviour and a number of physiological features (Zettel & Zettel, in press).

During three winters we carried out experiments dealing with the following questions: which part of the population is able to be active on the snow surface from early to late winter and how do the animals behave in the snow - litter profile?

Leinaas (1981c) presented some data on collembolan activity in the snow cover, but due to the low population density of *I.hiemalis*, there are no essential findings on our species.

Methods

Population samples were collected from the litter or snow surface in late autumn and early winter and exposed to natural conditions in open perspex cylinders (diameter 20 cm, height 2 m) with an animal-free litter layer. During winter an undisturbed snow profile developed in the cylinders, which contained 300 springtails each. After 1-6 months the cylinders were collected under different weather conditions, the snow columns extracted in fractions and the morphs and size classes of the Collembola contained in these fractions determined.

*supported by the Swiss National Research Foundation

Results

In early winter, a population of I.hiemalis is composed of individuals of the instars II - VII, which do not have an identical winter behaviour. Two main groups can be distinguished:

a) ca. 70% of all animals show a subitaneous development (S-animals). Their winter morph lasts as long as a normal instar (ca. one month at 0°C). Throughout winter, they mainly live in the litter layer.
b) ca. 30% of the population enter a dormancy (D-animals). They stop moulting, their winter morph thus lasting 2-5 months. During this time, they show a normal activity and may even feed. They mainly stay in the snow cover and appear on the snow surface under favourable weather conditions.

From our investigations of the free-living population we expect all S-animals to be back in the summer morph in January (fig. 2 in Zettel 1985), while the D-animals only start to moult to the summer morph. Consequently the percentage of the two morphs in January can be used as a measure for the division into D- and S-animals.
The hitherto used terms "litter animals" for a) and "snow animals" for b) are abandoned because we today know that "litter animals" may well leave the litter and "snow animals" retreat into the litter layer.
Juveniles are almost exclusively S-animals and subadults show a lower percentage of dormant individuals than adults (Table 1). By this the observed percentage of D- and S-

Table 1

Percentage of dormant (D) and subitaneously developing animals (S) in the larger instars of I.hiemalis. (VI = subadult, VII = adult). Data from a sample collected 6.11. 1983, examined 14.1.1984.
VI and VII provide more than 95% of the surface active individuals: adults show the biggest portion of dormant animals.

instar	D	S	n
IV	0	100	13
V	0	100	18
VI	46	54	178
VII	63	37	51
VI + VII	49	51	229

animals in a population depends on the age structure of the sample; however physiological findings indicate that the splitting up is not only size-dependent but that also a genetic polymorphism may be involved (Zettel 1985).

During January, the first dormant individuals are expected to moult back to the summer morph; in March less than 30% still belong to the hiemalis morph and in April only a few individuals can be found in this morph (Fig. 1b). Thus the number of potentially surface-active I.hiemalis declines continuously from early December (up to 60%, = VI and VII in the hiemalis morph) till late spring, when only a very few percents of the population can be expected on the snow surface, even when there is still a considerable snow cover.

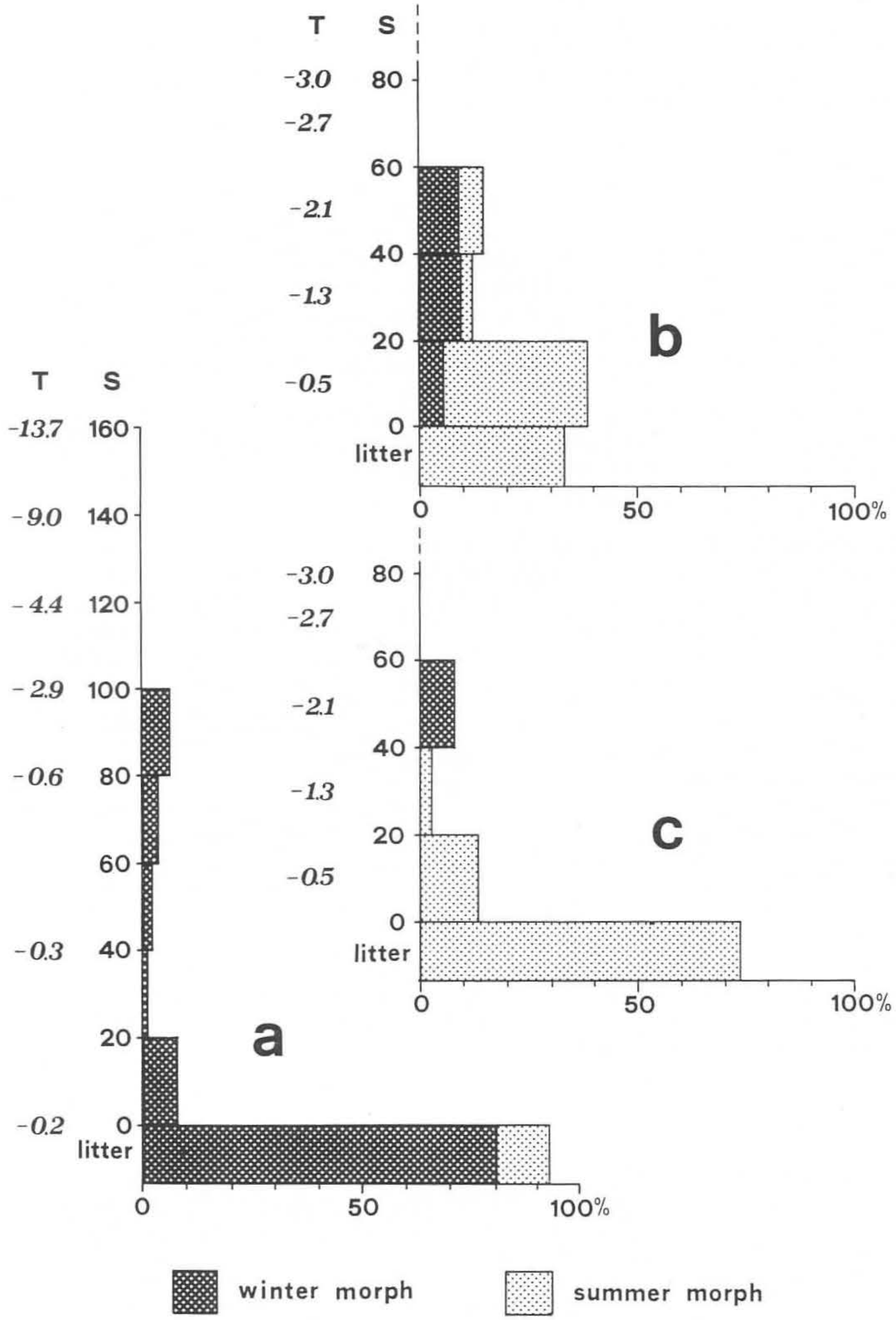
At favourable temperatures, D- and S-animals of the mucronata morph can be found within the snow until the last patches of snow have disappeared; the S-animals are usually concentrated near the soil (Fig. 1b,c).

Only animals of the winter morph are physiologically adapted to appear on the snow surface (Zettel & Zettel, in press): only they have the essential cold-hardiness, in particular the thermal hysteresis producing antifreeze agents protecting against inoculative freezing (Zettel 1984a) and react to barometric pressure changes (Zettel 1984b). Today we know that not only D-, but also S-animals during their short winter morph may appear on the snow, especially on the first freshly fallen snow: samples collected under such conditions in early December included up to 36% S-animals.
On the other hand, D-animals (also of the hiemalis morph) retreat into the litter layer at low air temperatures, even under a deep snow cover which provides an excellent insulation (Fig. 1a).

In spite of the impossibility of collecting D- and S-animals properly separated in early winter, all findings so far are complementary. Still unsolved is the problem of the determination into D- and S-animals. Experiments referring to this question are under way.

Conclusions

The cyclomorphosis of I.hiemalis determines the surface activity, because only animals of the winter morph are adapted to activity in a frozen environment at temperatures below the freezing point of the hemolymph. Individuals of the summer morph (D- as well as S-animals) move up and down in the snow cover or stay in the litter layer, depending on the snow temperatures.



T
S
-3.0
80
-2.7
60
-2.1
40
-1.3
20
-0.5
0
litter
0
50
100%
b
T
S
-13.7
160
-9.0
140
-4.4
120
-2.9
100
-0.6
80
60
-0.3
40
20
-0.2
0
litter
0
50
100%
a
c
winter morph
summer morph

Fig. 1

Distribution of I.hiemalis in the snow - litter profile. Snow temperatures in °C (T), snow depth above ground in cm (S).

a) 27.1.86. Origin of sample: snow surface, early December. At the end of a cold spell, more than 80% of the D-animals stay in the litter layer. Low snow temperatures (threshold = -3°C) prevent I.hiemalis from appearing on the snow surface. A few S-animals are included in the sample.

b) 20.3.1984. Origin of sample: snow surface, 18.12.1983 (15 cm of snow).
76% are already in the summer morph, the main part of the (D-)animals stays in the snow; some of the mucronata animals may be S-animals collected on the surface in December.

c) 20.3.1984. Origin of sample: litter layer, 18.12.1983 (15 cm of snow); exposed in the same cylinder as b), those animals marked by clipping partly one antenna for identification.
The main part of the (S-)animals is in the litter layer. Obviously, the sample included some D-animals, still in winter morph and now staying near the snow surface.

References

Fjellberg A (1976) Cyclomorphosis in Isotoma hiemalis Schött, 1893 (mucronata Axelson, 1900) syn.nov.(Collembola, Isotomidae). Rev Ecol Biol Sol 13: 221-222.

Leinaas H P (1981a) Cyclomorphosis in the furca of the winter active Collembola Hypogastrura socialis (Uzel). Ent Scand 12: 35-38.

Leinaas H P (1981b) Cyclomorphosis in Hypogastrura lapponica (Axelson, 1902)(= H.frigida [Axelson, 1905] syn.nov.) (Collembola, Poduridae). Morphological adaptations and selection for winter dispersal. Z Zool Syst Evolutforsch 19: 278-285.

Leinaas H P (1981c) Activity of arthropoda in snow within a coniferous forest, with special reference to Collembola. Holarct Ecol 4: 127-138.

Zettel J (1984) Cold hardiness strategies and thermal hysteresis in Collembola. Rev Ecol Biol Sol 21: 189-203.

Zettel J (1985) Die Cyclomorphose von Isotoma hiemalis (Collembola): endogene Steuerung, phänologische und physiologische Aspekte. Zool Jb Syst 112: 383-404.

Zettel J, Zettel U (in press) Adaptations to winter activity in Isotoma hiemalis (Collembola). Proc IX Int Coll Soil Zool Moscow 1985.